PATENT ABSTRACTS OF JAPAN

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(54) MANUFACTURE OF METALLIC FOAMED BODY

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a method of manufacture of metallic foamed body, capable of inexpensively manufacturing a product of desired shape at arbitrary foaming ratio and also capable of facilitating foaming, with certainty, by the use of equipment of simplified structure under atmospheric pressure.

SOLUTION: One or more kinds among metals, alloys, and metal matrix composites, each having ≥ 420°C melting point, are heated and formed into molten metal of <630°C having ≤35% solid phase ratio by volume ratio. Titanium hydride in the amount of 0.1-5% by weight ratio is added to the molten metal and uniformly dispersed in the molten metal by agitation, and this molten metal, containing titanium hydride, in a proper quantity is poured into a mold or a metal product. Then, the molten metal in the mold or the metal product is reheated to ≥630°C to undergo foaming treatment, followed by solidification by cooling. By this method, the metallic foamed body of prescribed shape can be obtained.

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CLAIMS

[Claim(s)]
[Claim 1] A part of gas constituents required for the foaming agent added later making one or more sorts of a metal, an alloy, and metal matrix composite foam into a molten metal are heated in a temperature region maintainable in the condition of not dissociating. It accomplishes with the molten metal which consists of a liquid phase single phase in which mechanical homogeneity stirring is possible, or ** and a liquid phase mixing phase. After carrying out homogeneity distribution into a molten metal by adding and stirring the foaming agent of 0.1 - 5% of amount by the weight ratio to this molten metal, After carrying out teeming of the molten metal of the suitable amount containing this foaming agent to mold or metal goods, reheating the molten metal in mold or metal goods subsequently to the foaming temperature more than said dissociation temperature and carrying out foaming processing of the molten metal, by carrying out cooling coagulation The manufacture approach of the metal foam characterized by obtaining the metal foam of a predetermined configuration.
[Claim 2] The melting point heats one or more sorts of a metal 420 degrees C or more, an alloy, and metal matrix composite. After carrying out homogeneity distribution into a molten metal by accomplishing the rate of solid phase with a less than 630-degree C molten metal 35% or less by the volume ratio, and adding and stirring the titanium hydride of 0.1 - 5% of amount by the weight ratio to this molten metal, After carrying out teeming of the molten metal of the suitable amount containing this titanium hydride to mold or metal goods, reheating the molten metal in mold or metal goods subsequently to 630 degrees C or more and carrying out foaming processing of the molten metal, by carrying out cooling coagulation The manufacture approach of the metal foam characterized by obtaining the metal foam of a predetermined configuration.
[Claim 3] A part of gas constituents required for the foaming agent added later making one or more sorts of a metal, an alloy, and metal matrix composite foam into a molten metal are heated in a temperature region maintainable in the condition of not dissociating. It accomplishes with the molten metal which consists of a liquid phase single phase in which mechanical homogeneity stirring is possible, or ** and a liquid phase mixing phase. After carrying out homogeneity distribution into a molten metal by adding and stirring the foaming agent of 0.1 - 5% of amount by the weight ratio to this molten metal, Cooling coagulation is carried out, where it came out of the molten metal of the suitable amount containing this foaming agent as it was or teeming is carried out to mold or metal goods. Slab, Cast primary raw materials, such as a rod, and this primary raw material is processed into secondary raw materials, such as a pellet, a chip, a wire rod, and a plate, by rolling, cutting, cutting, etc. The manufacture approach of the metal foam characterized by obtaining the metal foam of a predetermined configuration by carrying out suitable amount insertion of this secondary raw material into mold or metal goods, and carrying out cooling coagulation after reheating subsequently to the foaming temperature more than said dissociation temperature and carrying out foaming processing.
[Claim 4] The melting point heats one or more sorts of a metal 420 degrees C or more, an alloy, and metal matrix composite. After carrying out homogeneity distribution into a molten metal by accomplishing the rate of solid phase with a less than 630-degree C molten metal 35% or less by the volume ratio, and adding and stirring the titanium hydride of 0.1 - 5% of amount by the weight ratio to this molten metal, Cooling coagulation is carried out, where it came out of the molten metal of the suitable amount containing this titanium hydride as it was or teeming is carried out to mold or metal goods. Slab, Cast primary raw materials, such as a rod, and this primary raw material is processed into secondary raw materials, such as a pellet, a chip, a wire rod, and a plate, by rolling, cutting, cutting, etc. The manufacture approach of the metal foam characterized by obtaining the metal foam of a predetermined configuration by carrying out suitable amount insertion of this secondary raw material into mold or metal goods, and carrying out cooling coagulation after reheating subsequently to 630

degrees C or more and carrying out foaming processing.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the manufacture approach of the metal foam used for extensive members, such as a structural material, ** (**) sound material, impact shock absorbing material, and a heat insulator, and relates to the manufacture approach of the suitable metal foam for manufacture of sheet metal, a bar, a pipe, or the product of a complicated configuration especially.
[0002]
[Description of the Prior Art] A foaming agent is added as a typical thing of the manufacture approach of conventional metal foam, stirring a molten metal metal, there are an approach of casting foaming melt to mold, and the approach of mixing metal powder and a foaming agent in the state of powder, and carrying out heating foaming, and two examples, for example, a Japanese Patent Publication No. 36-No. 20351 official report (the 1st example) and a Japanese Patent Publication No. 39-No. 803 official report (the 2nd example), are given as well-known advanced technology.
[0003] In these two examples, the method of mainly using a hydride for a foaming agent and manufacturing metal foam continuously is indicated by the 1st example, and, on the other hand, the method of carrying out the heating dissolution of what mixed the particle which generates gas, and metal particles, and manufacturing metal foam is indicated by the 2nd example at it.
[0004]
[Problem(s) to be Solved by the Invention] In the case of said 1st example, to the dissociation temperature of the hydrogen in a foaming agent, since the temperature of molten metal is quite high, foaming time amount must become short, and foaming melt must be dealt with and fabricated in general within 1 minute. That is, since a fluidity will worsen if the amount of generation of gas is the inner thing which does not reach to 25% and exceeds this, the mixed foam taken out from a mixing chamber must be extracted in the mold fabricated in a short time for less than 1 minute. Consequently, although it is suitable for manufacturing Plastic solids of a simple configuration, such as slab and an about 10cm comparatively thick thick plate, in large quantities, it is very difficult to manufacture the foam of a complicated configuration or to manufacture about dozens of mm sheet metal. Moreover, although dissociation of foaming gas is controllable, there is a problem to which a facility becomes large-scale and a manufacturing cost becomes high under the high-pressure force of 100 atmospheric-pressure extent.
[0005] On the other hand, in said 2nd example, it is a problem that the means of particle creation and homogeneity mixing takes long time amount and high cost. Moreover, although it is an approach [grinding that which quenched before the mixture foamed, and making it foam by making it the shape of a particle] after mixing to the molten metal held near the congealing point, using a hydride content metal alloy as a foaming agent In the melting point of an alloy which has been hung up now over the example in the 2nd example the hydrogen of a hydride content alloy -- ordinary pressure -- the whole quantity -- **** -- since it dissociates quickly, in order to mix a hydride content alloy to molten metal at homogeneity, without foaming, it is necessary to manufacture under the high-pressure force, therefore a facility is complicated, and the disadvantage used as high cost must have been escaped.
[0006] In recent years, metal foam has been manufactured like by these approaches of solidifying, after carrying out mixed distribution and making it mainly foam to aluminum and an aluminium alloy by using a hydride as a foaming agent. In this case, it is high in a melting temperature, and also according to the example in a well-known example, it is manufactured at the temperature of 630 degrees C or more so that clearly. In order that a

hydride may dissociate hydrogen violently under atmospheric pressure at this temperature, in order to mix a foaming agent to homogeneity in a molten metal, it is necessary to perform very powerful stirring. Moreover, in order that a molten metal may foam quickly, in order handling is difficult and to cast with the mold of a complicated configuration, while a manufacturing installation becomes complicated, the problem which cost attaches remarkably highly is not avoided.

[0007] Accomplishing [therefore] this invention in order to aim at the dissolution of such a trouble, the main purpose of this invention is to offer the manufacture approach of metal foam which becomes possible [manufacturing cheaply / are the expansion ratio of arbitration and / the product of the configuration made difficult in Prior arts, such as a product of a complicated configuration, sheet metal, and a pipe,].

[0008] Foaming molding of other purposes of this invention can be carried out certainly and easily under atmospheric pressure with a facility of easy structure, and they are by the ability performing foaming control free moreover to offer the manufacture approach of metal foam which becomes size the place which is rich in versatility.

[0009]

[Means for Solving the Problem] This invention is considered as the configuration described below in order to attain the above-mentioned purpose. Namely, this invention is heated in the temperature region which can maintain a part of gas constituents required for the foaming agent added later making one or more sorts of a metal, an alloy, and metal matrix composite foam into a molten metal in the condition of not dissociating. It accomplishes with the molten metal which consists of a liquid phase single phase in which mechanical homogeneity stirring is possible, or ** and a liquid phase mixing phase. After carrying out homogeneity distribution into a molten metal by adding and stirring the foaming agent of 0.1 - 5% of amount by the weight ratio to this molten metal, After carrying out teeming of the molten metal of the suitable amount containing this foaming agent to mold or metal goods, reheating the molten metal in mold or metal goods subsequently to the foaming temperature more than said dissociation temperature and carrying out foaming processing of the molten metal, by carrying out cooling coagulation It is the manufacture approach of the metal foam characterized by obtaining the metal foam of a predetermined configuration.

[0010] As for this invention, the melting point heats one or more sorts of a metal 420 degrees C or more, an alloy, and metal matrix composite again. After carrying out homogeneity distribution into a molten metal by accomplishing the rate of solid phase with a less than 630-degree C molten metal 35% or less by the volume ratio, and adding and stirring the titanium hydride of 0.1 - 5% of amount by the weight ratio to this molten metal, After carrying out teeming of the molten metal of the suitable amount containing this titanium hydride to mold or metal goods, reheating the molten metal in mold or metal goods subsequently to 630 degrees C or more and carrying out foaming processing of the molten metal, by carrying out cooling coagulation It is the manufacture approach of the metal foam characterized by obtaining the metal foam of a predetermined configuration.

[0011] This invention is heated in the temperature region which can maintain a part of gas constituents required for the foaming agent added later making one or more sorts of a metal, an alloy, and metal matrix composite foam into a molten metal again in the condition of not dissociating. It accomplishes with the molten metal which consists of a liquid phase single phase in which mechanical homogeneity stirring is possible, or ** and a liquid phase mixing phase. After carrying out homogeneity distribution into a molten metal by adding and stirring the foaming agent of 0.1 - 5% of amount by the weight ratio to this molten metal, Cooling coagulation is carried out, where it came out of the molten metal of the suitable amount containing this foaming agent as it was or teeming is carried out to mold or metal goods. Slab, Cast primary raw materials, such as a rod, and this primary raw material is processed into secondary raw materials, such as a pellet, a chip, a wire rod, and a plate, by rolling, cutting, cutting, etc. It is the manufacture approach of the metal foam characterized by obtaining the metal foam of a predetermined configuration by carrying out suitable amount insertion of this secondary raw material into mold or metal goods, and carrying out cooling coagulation, after reheating subsequently to the foaming temperature more than said dissociation temperature and carrying out foaming processing.

[0012] As for this invention, the melting point heats one or more sorts of a metal 420 degrees C or more, an alloy, and metal matrix composite again. After carrying out homogeneity distribution into a molten metal by accomplishing the rate of solid phase with a less than 630-degree C molten metal 35% or less by the volume ratio, and adding and stirring the titanium hydride of 0.1 - 5% of amount by the weight ratio to this molten metal, Cooling coagulation is carried out, where it came out of the molten metal of the suitable amount

containing this titanium hydride as it was or teeming is carried out to mold or metal goods. Slab, Cast primary raw materials, such as a rod, and this primary raw material is processed into secondary raw materials, such as a pellet, a chip, a wire rod, and a plate, by rolling, cutting, cutting, etc. It is the manufacture approach of the metal foam characterized by obtaining the metal foam of a predetermined configuration by carrying out suitable amount insertion of this secondary raw material into mold or metal goods, and carrying out cooling coagulation, after reheating subsequently to 630 degrees C or more and carrying out foaming processing.

[0013]

[Embodiment of the Invention] Hereafter, the desirable operation gestalt of this invention is explained concretely. As a result of this invention person's etc. repeating a technical examination wholeheartedly and conducting much experiments, dissociation of the gas of the foaming agent in the molten metal of the composite material of a metal, an alloy, or the metal base If it happens gradually and selection of an ingredient and a foaming agent is especially performed appropriately with temperature depending on temperature and a pressure when a pressure is fixed Even if it adds a foaming agent to a molten metal under atmospheric pressure, dissociation of gas is seldom caused. It is fixed and the knowledge of the ability to obtain foam by it being able to distribute to homogeneity in a molten metal, and initial-complement dissociation of the gas of a foaming agent being carried out, being able to make it foam by carrying out the temperature up of the molten metal which distributed this foaming agent, and cooling quickly by stirring, was carried out.

[0014] Moreover, when the rate of solid phase was 35% or less at this time, as for the molten metal, by stirring a foaming agent showed that it could distribute easily. In addition, although this molten metal has fine air bubbles, there are few those amounts and they have comparatively good fluidity nature. Moreover, if the addition of a foaming agent is suitable, it is possible to foam to 90% or more of void volume by carrying out a heating temperature up beyond the temperature which fully dissociates the gas [melt / this] according to a foaming agent. Therefore, after it casts the melt (+ foaming agents, such as an alloy) of optimum dose so that it may become the target expansion ratio to the mold of a complicated configuration, and heating beyond the temperature which fully dissociates gas the whole mold and foaming in [whole] mold, it can be made to be able to quench and solidify and the foam of the target configuration can be obtained. A foaming agent here can apply hydrides (titanium hydride, hydrogenation zircon, etc.), carbonates (a calcium carbonate, carbonic acid MAGUNESHIU, etc.), hydrates (milt etc.), etc.

[0015] When the concrete example was given here, at less than 630 degrees C, dissociation of the hydrogen of the foaming agent realized with the titanium hydride in the alloy which mainly used aluminum or magnesium as the base is little, and is a part, and came to carry out the knowledge of it being 630 degrees C or more for a dissociation rate to be also slow in comparison and to dissociate hydrogen remarkably. Moreover, when the rate of solid phase carries out mixed stirring of the titanium hydride at less than 630 degrees C into the molten metal of 35% or less of solid-liquid mixing two-phase region or a liquid phase single phase also showed that titanium hydride could be distributed easily.

[0016] Although this molten metal contains fine air bubbles, that amount has few comparatively good fluidity nature. Moreover, if the addition of titanium hydride is suitable, it is possible to foam to 90% or more of void volume by heating this melt at 630 degrees C or more. Therefore, the melt (alloy + titanium hydride) of optimum dose is cast so that it may become the target expansion ratio to the mold of a complicated configuration, it heats at every mold 630 degrees C or more, after foaming in [whole] mold, it can quench, and it can be made to be able to solidify, and the foam of the target configuration can be obtained.

[0017] Namely, the melting point heats one or more sorts of a metal 420 degrees C or more, an alloy, and metal matrix composite. After carrying out homogeneity distribution into a molten metal by accomplishing with 35% or less of rates of solid phase, and a less than 630-degree C molten metal, and adding and stirring the titanium hydride of 0.1 - 5% of amount by the weight ratio to this molten metal, After carrying out teeming of the molten metal of the suitable amount containing this titanium hydride to mold or metal goods, reheating the molten metal in mold or metal goods subsequently to 630 degrees C or more and carrying out foaming processing of the molten metal, it becomes possible by carrying out cooling coagulation to obtain the metal foam of a predetermined configuration.

[0018] Detail of each manufacture conditions is given below. If the melting point is less than 420 degrees C, it must cool quickly that a temperature gradient 200 degrees C or more is in making the melt made to foam above 630 degrees C solidify. In this case, if time amount after foaming until it solidifies is long, when air bubbles will join together, big and rough-ization of the air bubbles resulting from carrying out defoaming arises, contraction

becomes large because the internal pressure of air bubbles falls, and it becomes difficult to establish the target configuration. therefore, the part in the foaming agent which adds the melting point -- it must be so desirable that it is near and high temperature to the dissociation temperature which little gas begins to separate, and must be 420 degrees C or more as it is low.

[0019] Next, although it is about the process which makes the molten metal used as foam distribute the titanium hydride used as a foaming agent, it is necessary to make the temperature into less than 630 degrees C. Above 630 degrees C, the hydrogen dissociative reaction of titanium hydride becomes remarkable, and metal melt comes to have many air bubbles, therefore the handling of melt becomes difficult by the fall of fluidity nature. In that respect, titanium hydride can fully be distributed by dissociation of the hydrogen of titanium hydride being slow if it is less than 630 degrees C, and stirring a molten metal. At this time, the molten metal may include 35% or less of solid phase.

[0020] However, if the solid phase to contain exceeds 35%, in order that not only stirring effectiveness falls, but solid phase particles may contact during stirring, viscosity may increase extremely and a solid phase particle may make it big and rough, it becomes difficult to make homogeneity distribute titanium hydride. Therefore, the rate of solid phase of a molten metal is made into 35% or less. In addition, the solid phase said in this specification is the thing of the wide sense also containing ingredients other than base materials, such as ceramics which it is not restricted to stoichiometry-solid phase and the base material of a metal or an alloy is made to add intentionally.

[0021] Homogeneity is made to distribute titanium hydride in a molten metal by stirring by weight % to the above-mentioned molten metal by adding the titanium hydride of the suitable amount between 0.1% and 5%. It is an amount with less than 0.1% insufficient [titanium hydride] for making homogeneity distribute and foam into a molten metal. Moreover, when it exceeds 5%, even if it is less than 630 degrees C, the amount of dissociation of hydrogen increases, the viscosity of a molten metal increases, and handling causes about [becoming difficult] and cost quantity. Therefore, let the addition of titanium hydride be 0.1 - 5% of range.

[0022] Next, titanium hydride carries out suitable amount teeming of the less than 630-degree C molten metal which distributes to homogeneity and it comes to contain to metal goods to make it fill up with mold or foam. Here, a suitable amount is an amount which calculated the weight which carries out teeming from the consistency for which it asks, and the volume of foam, and, of course, are a runner and the value as which the amount of the dead head was also considered. Subsequently, the molten metal which carried out teeming is heated at 630 degrees C or more, and hydrogen is made to dissociate and it is made to foam from the titanium hydride to contain. If the target configuration and expansion ratio are reached, it is necessary to quench immediately and to make it solidify. Although cooling temperature changes with the configurations and magnitude of a product, as for foam, as for a lifting and its extent, a cooling rate becomes so small that it is quick about contraction in the case of coagulation. Therefore, it is necessary to set up a cooling rate according to the need dimensional accuracy of a product. It is possible to manufacture metal foam certainly and easily through these processes.

[0023] Moreover, after this invention makes the molten metal which distributed the foaming agent the configuration of slab, a rod, etc. and makes it cool and solidify as it is, it is possible to also make it foam by machining rolling, cutting, etc., making it the configuration of arbitration, such as sheet metal and a bar, and a chip, making these into a suitable configuration and weight, and reheating in mold and a furnace etc. By this approach, since a dimension and weight can be made to foam with a sufficient precision with mold etc., it is an approach suitable for manufacture of the product with which the precision of dimensional accuracy or apparent density is demanded.

[0024]

[Example] Hereafter, it explains, contrasting with the example of comparative experiments about the concrete example of this invention approach. The chemical entity and manufacture conditions including a **** example and each example of a comparison of a test specimen are shown in the following table 1. By the atmospheric-air dissolution, 3kg dissolved and all were performed. It adds in 30 seconds, and titanium hydride (Ti H2) stirred the molten metal for 1 minute, and was distributed. The molten metal was cast on the 30mmx100mm prism and the cylinder of 30mmphi, and it reheated to predetermined temperature in the furnace the whole mold. When a foaming phenomenon was completed, mold was taken out from the inside of a furnace, and forced-air cooling was given. Expansion ratio was computed from the relational expression of x(alloy consistency-foam consistency) 100-/alloy consistency. The rate of solid phase was computed from the rate of area of an

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organization. Homogeneity displayed that to which the maximum of a consistency exceeds the twice of the minimum value as x, what is not exceeded was displayed as O, and dimensional accuracy displayed as O what does not have x and a difference in what had the difference 2% or more.

[0025] Homogeneity and dimensional accuracy of expansion ratio were [the examples 1, 2, and 4 of an experiment of this invention material] all good at 90% or more. To these, since reheating temperature was 610 degrees C, the example 3 of an experiment which is comparison material had few amounts of dissociation of hydrogen, and it could not fully foam for it, but remarkable dispersion was in homogeneity. The example 5 of an experiment which is comparison material has titanium hydride as little as 0.06 % of the weight, there are very few amounts of dissociation of hydrogen, and it cannot fully foam, there is remarkable dispersion in respect of homogeneity, and dimensional accuracy also brought a bad result.

[0026]

[Table 1]

表1 化学成分及び製造条件並びに試作結果

		Al 重量%	Cu 重量%	Mg 重量%	Ca 重量%	Si 重量%	TiH_2 重量%	融点 (℃)	固相率 (体積率) (%)	TiH_2添加温度 (℃)	再加熱温度 (℃)	発泡率 (%)	均一性	寸法精度
実験例1	本発明材	残部	15.0	0.01	1.5	0.01	1.5	548～610	10	600	680	91	○	○
実験例2	本発明材	30.0	0.02	68.2	<0.01	<0.01	1.5	437～445	0	550	640	90	○	○
実験例3	比較材	〃	〃	〃	〃	〃	〃	〃	0	550	610	45	×	○
実験例4	本発明材	残部	0.01	<0.01	1.5	11.5	1.5	575～580	0	600	680	92	○	○
実験例5	比較材	残部	15.0	0.01	1.5	0.01	0.06	548～610	10	600	680	30	×	×
実験例6	比較材	残部	4.5	1.5	<0.01	1.0	1.5	520～635	37	600	680	83	×	×
実験例7	比較材	〃	〃	〃	〃	〃	〃	〃	0	680	680	95	注湯不可	注湯不可

注、残部：他の成分を除いた残り全量（不可避的成分を含む）、

[0027] On the other hand, since the example 6 of an experiment which is comparison material had the rate of solid phase as large as 37% at the time of adding titanium hydride and making it distribute, it could not be made to fully distribute, but it is set to homogeneity and dimensional accuracy, and was inferior also in the gap. Since the temperature when adding titanium hydride was as high as 680 degrees C, dissociation of hydrogen was performed violently, and since foaming advanced while having added and stirred titanium hydride, the viscosity of foaming melt was not able to become high and was not able to carry out teeming of the example 7 of an experiment which is comparison material to mold.

[0028] Moreover, the molten metal obtained in the example 1 of an experiment is used as slab with a thickness of 6mm, and quenching and coagulation of were done, and this was rolled out and it was made 1.4mm sheet metal. After making this sheet metal heat and foam at 660 degrees C within the griddle of a height a tooth space of 15mm, the foaming plate which was excellent in the homogeneity of 93% of expansion ratio and dimensional accuracy with 15mm in thickness was producible by carrying out forced-air cooling.

[0029] Furthermore, it is cutting processing about the slab which obtained the molten metal obtained in the example 1 of an experiment by making it quench and solidify. The foam of the cylinder whose dimensional accuracy is less than 1% and whose apparent density is 0.30g [cc] /, 0.40g [cc] /, and 0.50g/cc was able to be obtained by producing to the block of 30g, 40g, and 50g, inserting these in in 100 cc mold with a cylindrical shape with a diameter of 60mm, making it reheat and foam at 680 degrees C, and carrying out forced cooling.

[0030]

[Effect of the Invention] If it is the mold which can be heated beyond the foaming temperature of a foaming agent since the two-step heating method is taken and fluidity nature is in a molten metal by the manufacture approach of the metal foam by this invention even after distributing the foaming agent like titanium hydride as stated above, the foam of the configuration of arbitration can be manufactured certainly and easily. Moreover, since there is also no time constraint to casting after adding pressure control and a foaming agent, with an easy facility, it is possible to manufacture metal foam, and it can compare with this seed manufacture approach proposed by the present, and can manufacture cheaply and easily.

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